UNHOLTZ-DICKIE CORPORATION

vibration generation systems and measurement instruments

Accelerometer

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UNHOLTZ-DICKIE CORPORATION
2994 WHITNEY AVENUE
HAMDEN, CONNECTICUT 06518
PHONE (203) 288-3358

ACCELEROMETER

OPERATING AND INSTRUCTION MANUAL

1. Introduction

This accelerometer is a transducer which converts a vibratory acceleration into an electrical signal. It contains a piezoelectric crystal, one side of which is connected to an inertial mass. The other face of the crystal is fastened to the accelerometer base which is mounted at the place where the vibration or shock is to be sensed. During acceleration the inertial mass exerts a force on the crystal which is F = Ma (inertial mass times acceleration). The piezoelectric crystal has the property of producing an electrical signal proportional to the amount of mechanical deformation of the crystal. In the accelerometer this deformation is caused by the inertial force of the mass acting on the crystal face. The mechanical deformation of the crystal may be either in the shear mode or in the compression mode. These two general types of accelerometer construction are illustrated in Figs 1 and 2. In the shear type design the crystal is manufactured in the form of a cylinder, and the inertial weight serves to displace one surface of the cylinder with respect to the other. Alternatively the piezoelectric material may be made into discs which are stacked with the inertial weight on top. The stack of crystal discs is then placed under a preload. Under acceleration the weight compresses or decompresses the stack of discs and produces an electrical signal.

The electrical signal put out by the accelerometer may be sensed as either an electrical charge or an electrical voltage, depending on the type of instrument used to measure the signal. Fig 3 shows the simplified charge equivalent circuit of an accelerometer connected to a charge amplifier, and Fig 4 shows the same charge equivalent circuit into a voltage amplifier. Note that in both cases the charge equivalent circuit of the accelerometer is used. A voltage equivalent circuit is also possible but it is less simple to analyze and the location of the capacitances is more artificial. In the circuits of Figs 3 and 4 the capacitances of the cable and amplifier inputs are located to correspond with our intuitive understanding of their physical location. For example, cable capacitance is shown from one lead to the other, corresponding to the capacitance that exists between the center conductor and the shield of a cable.

Historically, voltage amplifiers preceded charge amplifiers

and thus many existing types of accelerometers are designed for optimal performance with a voltage amplifier. These types may still be used with a charge amplifier, usually under more restricted temperature conditions. Other accelerometers are designed for optimal use with charge amplifiers, and yield a flat response with variations in frequency and temperature. The basic advantages of a voltage instrument are (1) lower cost and (2) less circuitry. The advantages of a charge instrument are (1) it allows the use of very long accelerometer cables - up to 1 mile - and (2) one calibration setting per accelerometer is sufficient, regardless of cable length and cable capacitance. With a voltage amplifier, three items must be handled: (1) voltage sensitivity, (2) accelerometer capacitance and (3) cable capacitance. With a charge amplifier only the charge sensitivity is necessary. With modern accelerometers having large voltage sensitivity, voltage instruments may be used with moderately long cable lengths. Since voltage sensitivity drops with an increase in cable capacitance for a given accelerometer, care must be taken that the signal-to-noise ratio does not become too large when cable length is increased.

2. Sensitivity

2.1 General

The sensitivity of an accelerometer is defined as the ratio of the electrical output signal to the mechanical input. Output signals may be in millivolts or picocoulombs, and input is usually expressed in terms of multiples of the acceleration of gravity, or "g"s. Sensitivity is therefore expressed in millivolts per "g" or picocoulombs per "g". Since the output waveform at calibration is sinusoidal and may be described in several ways, it is important to note whether the sensitivity is expressed in <u>rms</u> millivolts per g or in <u>peak</u> millivolts per g. Sensitivity in a uniaxial accelerometer is measured along a single axis of the accelerometer called the sensitive axis or major axis. Polarity of the accelerometer output has been standardized by the industry such that an acceleration directed from the mounting surface into the body of the accelerometer will produce a positive charge or voltage on the "high" side of the output connector on the transducer. It must be noted that if phase information is important, the test engineer should check the polarity of the charge or voltage amplifiers used, as some amplifiers introduce an inversion stage into the circuit.

2.2 Voltage Sensitivity

The charge equivalent circuit leads to the simplest calculation of voltage sensitivity for any load capacitances. The loaded voltage sensitivity (S_L) is simply the charge sensitivity (Q) in pk-pC/g-pk divided by the sum of the accelerometer capacitance, the cable capacitance and the amplifier input capacitance. The cable and input capacitances are usually added together and called the load capacitance (C_L). Thus:

$$S_L = \frac{Q \times 1000}{C_{Accel} + C_{cable} + C_{input}} = \frac{Q \times 1000}{C_A + C_L} \frac{mv\text{-}pk}{g - pk} \qquad (1)$$

All Unholtz-Dickie voltage amplifier sensitivity dials are calibrated in rms millivolts per peak g. To calculate rms sensitivity from peak sensitivity, multiply the peak sensitivity by 0.707.

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Example 2.1:

Given the Model 20D21 Accelerometer with a charge sensitivity of 35 pC-pk/g-pk and an internal capacitance of 1600 pF, determine the voltage sensitivity to be dialed on a Model CV608-R amplifier in the voltage mode. Assume that the amplifier input capacitance is 10 pF and the cable connecting the accelerometer output to the amplifier has 305 pF capacitance. Note that the Model CV608-R requires <u>rms</u> mv per peak g sensitivity.

Answer:

$$S_L = \frac{Q \times 1000}{C_A + C_L} = \frac{35 \times 10^{-12} \times 10^3}{(1600 + 305 + 10) \times 10^{-12}}$$

$\therefore S_L = 18.3$ pk-mV/g-pk

To calculate rms sensitivity from peak sensitivity, multiply by 0.707:

$\therefore S_L = 12.9$ mV-rms/g-pk

- -

With the use of the concept of open-circuit voltage sensitivity (S_{oc}) we can provide another method for calculating loaded voltage sensitivities. The open-circuit voltage sensitivity is defined as:

$$S_{oc} = \frac{Q \times 1000}{C_A} \text{ pk-mV/g-pk} \qquad (2)$$

Combining equations (1) and (2) we have

$$S_L = S_{oc} \frac{C_A}{C_A + C_L} \text{ pk-mV/g-pk} \qquad (3)$$

If the accelerometer cable is changed, then the loaded voltage sensitivity S_L must be altered to reflect that change. If C_L' is the new load capacitance (cable + amplifier input capacitance) and S_L' is the new loaded voltage sensitivity, then from Equation (3) we can calculate that

$$S_L' = S_L \frac{C_A + C_L}{C_A + C_L'} \qquad (4)$$

- -

Example 2.2:

Given the Model 75D21 Accelerometer with a charge sensitivity of 82 pC-pk/g-pk and an internal capacitance of 1100 pF, determine the open-circuit voltage sensitivity. Then determine the voltage sensitivity to be dialed into a Model 602R Amplifier with 10 pF input capacitance using 175 feet of cable with 5340 pF cable capacitance. The Model 602 requires <u>rms</u> mv per peak g.

Answer:

$$S_{oc} = \frac{Q \times 1000}{C_A} = \frac{82 \text{ pC-pk/g-pk} \times 10^3}{1100 \text{ pF}}$$

$$S_{oc} = 74.5 \text{ mV-pk/g pk}$$

Then

$$S_L = S_{oc} \frac{C_A}{C_A + C_L} = 74.5 \frac{1100}{1100 + 5340 + 10}$$

For the Model 602 Amplifier, multiply by 0.707 to obtain the rms sensitivity; thus

$$S_L = 8.98 \text{ mV-rms/g-pk}$$

- -

Example 2.3:

Given the Model 5D21 Accelerometer with a loaded voltage sensitivity of 7.29 mV-rms/g-pk into a Model CV608R Amplifier using a 10 foot 310 pF cable, find the new voltage sensitivity using a 6 foot 180 pF cable. The accelerometer capacitance is 1600 pF.

Answer: Using Equation (4),

$$S_L' = S_L \frac{C_A + C_L}{C_A + C_L'}$$

$$= 7.29 \frac{1600 + 310 + 10}{1600 + 180 + 10}$$

$$S_L' = 7.82 \text{ mV-rms/g-pk}$$

- -

Figure 5 expresses Equation (1) in nomograph form. To use this nomogram to obtain the loaded voltage sensitivity S_L, place a straight edge between the given charge sensitivity on the right-hand column, and on the total capacitance, including the accelerometer, cable and input capacitances, on the left-hand column. Read the value of S_L on the center column in mV-peak per g-peak. Multiply this answer by 0.707 if the sensitivity in mV-rms/g-pk is needed. It may be necessary to correctly place the decimal point in the answer if $Q > 10$ or if $C_T > 4000$. In this case the orders of magnitude of the numbers representing Q, S_L, or C_T must be estimated so that the answer will be given correctly. This estimation is performed in the same way as when slide-rule calculations are made. Now, use the nomogram to recalculate the loaded voltage sensitivity in Example 2. Example 1 is already drawn in on the nomogram.

2.3 Charge Sensitivity

The charge sensitivity of an accelerometer is independent of cable capacitances or other load capacitances. To take advantage of this fact a charge amplifier must be used as the signal conditioning device. It is then necessary simply to dial the given charge sensitivity into the amplifier, being careful to distinguish between rms and peak sensitivities.

3. Accelerometer Characteristics

3.1 General

In considering the accuracy of measurements made with an accelerometer, a number of factors should be taken into account. For a given accelerometer, variations in sensitivity within specified limits

occur over a frequency range, a temperature range, and over a dynamic range. In addition, cross-axis sensitivity, case and base thermal shock sensitivity, base strain sensitivity and cable whip sensitivity all can affect measurements. Fortunately, in a modern, well-designed accelerometer, many of these effects can be minimized and are negligible. Some of these accelerometer characteristics can be varied by the choice of piezoelectric material and by the mechanical design utilized.

3.2 High Frequency Response

A typical accelerometer has an approximately flat sensitivity vs frequency curve in the usable band from a few Hertz to thousands of Hertz. At the upper end of this frequency band the sensitivity of the accelerometer starts to increase. The spring-mass resonance of the accelerometer, which occurs at a much higher frequency, results in an increased output for a given input. Fig 6 shows this rising response on a normalized frequency basis for an undamped resonant system. From the curve it is seen that at approximately 1/5 of the natural frequency (0.2 on the normalized scale) the response is up about 4%. This point is generally taken as the upper frequency limit of the accelerometer. In other cases the upper frequency limit is set at that frequency at which the response is actually up 5%. For example, the Model 20D21 has a resonant frequency of 30,000 Hz, nominal specification. On its specification sheet the useful upper frequency limit is given as 6,000 Hz, which is 1/5 of 30,000 Hz. Above 6,000 Hz the sensitivity has risen more than 4% and is rising with increasing frequency. For making measurements above 6,000 Hz either an accelerometer with a higher resonant frequency can be used, or corrections may be made to data points to compensate for the resonant rise. A higher natural frequency is usually achieved by making the accelerometer smaller and/or less sensitive. The accelerometer resonant frequency mentioned above is a mounted resonant frequency. This is the lowest resonant frequency obtained and is measured with the accelerometer attached to a relatively very heavy mass, approaching an infinite mass with respect to the accelerometer itself.

3.3 Low Frequency Response

3.3.1 Charge Amplifier Operation

When the accelerometer is used with a charge amplifier the low

frequency limit is that of the charge amplifier alone. This is usually about 2 Hz or lower. Below this frequency the amplifier output is no longer flat, and the combined accelerometer - amplifier response will drop with decreasing frequency. As is the case with the charge sensitivity, the low frequency response when using a charge amplifier is not affected by the cable or accelerometer capacitances.

3.3.2 Voltage Amplifier Operation

With a voltage amplifier the low frequency limit may be either the amplifier low frequency response or the result of the time constant of the combined RC circuit, where R is the amplifier input resistance and C is the accelerometer and cable capacitance. Figure 7 is a normalized curve of this low-frequency dropoff characteristic. Normally the low frequency limit of usefulness is taken to be that frequency at which the accelerometer - amplifier response is down 5%. An example may clarify the point:

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Example 3.1:

A Model 20D21 Accelerometer with 1600 pF capacitance is connected with a 300 pF cable to a voltage amplifier having an input resistance of 1000 megohms. Find the frequency at which the sensitivity is down 5%. Answer: From Fig 7 the 5% point (Relative response = 0.95) corresponds to fRC = 0.48. We want to solve for frequency:

$$C = 1600 \text{ pF} + 300 \text{ pF} = 1900 \text{ pF}$$

Then $f \times 10.0 \times 10^{8} \times 19 \times 10^{-10} = 0.48$

$$f = \frac{0.48}{190 \times 10^{-2}} = 0.25 \text{ Hz.}$$

Since the amplifier low frequency response is probably not this low, it alone would determine the low frequency limit.

- -

3.4 Sensitivity Variations with Temperature

The major determinant of the manner in which accelerometer voltage or charge sensitivity varies with temperature is the crystal material of which the accelerometer is made. Two types of crystal material will be considered and discussed here.

3.4.1 Lead Zirconate - Titanate Crystals

Normally the Unholtz-Dickie Accelerometers which use lead

zirconate-titanate as a sensing material are considered to be voltage accelerometers, since this material was chosen for highest sensitivity and temperature stability when operating into voltage amplifiers. They have higher variation in sensitivity vs. temperature when used in the charge mode. Fig 8 shows the voltage sensitivity variations over the ranges of temperature for a typical application of lead zirconate-titanate material. Note that the load (cable) capacitance can be chosen to optimize the sensitivity variations over a particular temperature range. The curves show that for room temperature operation the best cable to use is one with about one-half the capacitance of the accelerometer. Typical co-axial cables run about 29 or 30 pF per foot. When an accelerometer using lead zirconate-titanate is operated into a charge amplifier, the cable capacitance has no effect on the charge sensitivity variations with temperature. Thus the load capacitance in this case cannot be chosen to optimize the charge sensitivity. In general, the charge sensitivity will nominally vary ±5% over a temperature range from 0° F to +165° F.

3.4.2 Bismuth Strontium Titanate Crystals

If wide temperature ranges are encountered then the Unholtz-Dickie accelerometers using Bismuth Strontium Titanate may be used. This material is usually used in the charge mode of operation because of its excellent response to wide temperature variations. Typically, when used with a charge amplifier, the charge sensitivity will nominally vary less than ±5% over a temperature range from -300° F to +500° F. These accelerometers may also be used in the voltage mode with nearly the same variation in voltage sensitivity with temperature.

3.4.3 Temperature Cycling

Depolarization due to temperature cycling can be avoided by always loading the accelerometers while cycling. This applies to increasing as well as decreasing temperature. The depolarization is due to charge buildup on the crystals due to thermally induced stresses in the accelerometer structure.

3.5 Accelerometer Linearity - Sensitivity Variations with Dynamic Range

Most piezoelectric accelerometers are extremely linear over a very wide range of g levels. A dynamic range of 80 to 100 dB or more with less than 1% error is quite common. In fact, it is quite difficult

to measure the linearity error in an accelerometer, it is so small.

3.6 Cross-Axis Sensitivity

An output from an accelerometer when the accelerometer is driven at right angles to its sensitive axis is referred to as cross axis sensitivity. Good accelerometer design can in some cases keep this unwanted output below 3% of the major axis sensitivity. The cross-axis sensitivity has a maximum value in some direction of rotation about the major axis, and a minimum at a position 90° away from the maximum. A typical plot of the cross-axis sensitivity is shown in Fig 9 as a function of angle of rotation about the sensitive axis.

The cross-axis sensitivity is measured at a single frequency, below 200 Hz. The assumption is made that the cross-axis sensitivity remains essentially unchanged over the frequency range up to at least a few thousand Hertz. Actual measurement of this frequency response of cross-axis sensitivity leads to many uncertainties. However, many measurements of shaker cross-axis motion up to 10,000 Hz with many different type accelerometers lead us to believe that there are no major variations in accelerometer cross-axis sensitivity.

3.7 Case and Base Strain Sensitivity, Thermal Shock Sensitivity, Cable Whip Sensitivity

In a poorly designed accelerometer, where the crystal and mass are not sufficiently isolated from the accelerometer exterior housing, very sizeable outputs can result from causes unrelated to axial vibration. In every case, these unwanted outputs are caused by strains in the outer housing which strain the crystal, either directly or through the seismic mass. Fig 10 shows a typical poorly designed accelerometer. The case provides the spring loading of the mass on the crystal. If the case is subjected to a mechanical or thermal shock, it will be strained so as to change its dimensions slightly. This will change the compression loading of the mass on the crystal, and an output will result.

One of the simplest methods for checking an accelerometer for this case sensitivity is to apply a slight thermal shock to the case by switching on an incandescent light bulb placed a few feet from the accelerometer. When the light bulb is turned on the accelerometer

output may be observed on a meter or a scope. In a well-designed accelerometer the output from such a thermal shock is negligible. In poorly designed accelerometers, even the temperature changes resulting from air drafts in a normal room can give outputs of several "g's".

Another check for case sensitivity is the effect of cable whip. If the cable connector on the accelerometer has varying forces on it, these forces are transferred to the case, causing minute strains in the case. Again, with a good accelerometer design, such strains resulting from cable whipping will not result in a significant output signal. To check this, simply flex the accelerometer cable close to the connector, with the accelerometer mounted on a large rigid structure. Then connect the cable to a capacitance approximately equal to the accelerometer capacitance, and repeat the test. Any output from this cable flexing can be noted on a meter or a scope, and the observer may see any significant increase in output with the accelerometer attached to the cable.

Base strain sensitivity is similar to the case sensitivity described above. In some test environments the surface to which the accelerometer is attached is bending as well as vibrating. If this bending causes strains in the accelerometer base such that a significant output results, the accelerometer is said to be base strain sensitive.

Base strain sensitivity is checked by mounting the accelerometer at the inboard end of a cantilever beam, as in Fig 11. When the free end of the beam is vibrated at a known amplitude, a known strain is applied to the base of the accelerometer. Since the accelerometer under test is mounted near the clamped end of the beam, and since the frequency is low (typically 5 Hz) acceleration due to vertical motion of the beam at the point of mounting is negligible. The output of the test accelerometer may then be traced to base strain alone.

Base strain sensitivity is inherently very small in the shear mode design accelerometer shown in Fig 1. This design has probably the smallest base strain sensitivity of all. The compression design shown in Fig 2 has been made relatively free of base strain problems by special compromises, such as making the base very thick relative to the diameter to minimize strain, or building a double base which will not transmit the strains in the base to the crystal.

4. Instrumentation - Accelerometer Amplifiers

4.1 Voltage Amplifier Operation

A voltage amplifier is basically of the cathode-follower type, with a high resistive input impedance which ranges from several hundred to several thousand megohms in typical cases. Vibrating the accelerometer results in the production of a charge proportional to the acceleration which appears as a voltage across the accelerometer capacitance C_A and the cable capacitance C_c according to the equation

$$E = \frac{Q}{(C_A + C_c)}$$

This shows the dependence of the input voltage on the circuit capacitance when a voltage amplifier is used. The low frequency response of the accelerometer - voltage amplifier combination is determined by the time constant $R\ (C_A + C_c)$ where R is the input resistance of the amplifier. The higher the input resistance R, the higher the time constant; therefore the low-frequency cutoff is decreased with an increase in R.

4.2 Charge Amplifier Operation

The charge amplifier is a special type of operational amplifier with a relatively large capacitor in the feedback path. (See Fig 12) The amplification factor A is very large and negative, and the input impedance to A is very large. We consider this amplifier with a charge-equivalent accelerometer source: (See Fig 13)

$$i_1 = i_2 + i_3 \quad \text{(since input impedance to A is very large)}$$

$$Q = C_i e + C_f\ (e_i - e_o)$$

$$Q = \frac{C_i e_o}{A} + \frac{C_f e_o}{A} - C_f e_o \quad (\text{since } e_o = A e_i)$$

$$\frac{Q}{e_o} = \frac{C_i + C_f}{A} - C_f$$

If the quantity $\frac{C_i + C_f}{A}$ is negligible in comparison with C_f; that is, if the gain A is very large, $\frac{Q}{e_o} \cong -C_f$, or

$$e_o \cong -\frac{Q}{C_f}$$

In other words, the output voltage depends only on the charge input and not on the value of C_i.

The assumption was made that $\frac{C_i + C_f}{A} << C_f$. Let us see what variation of C_i would produce a 1% error, from this approximation:

Example 4.1

Let $A = 5000$

$C_f = 1000$ pF

$$\frac{C_i + C_f}{A} = \frac{C_f}{100} \quad \text{(that is, 1\% of } C_f\text{)}$$

Then $$\frac{C_i}{A} = C_f \left(\frac{1}{100} - \frac{1}{A}\right)$$

$$\therefore \quad C_i = C_f \left(\frac{A}{100} - 1\right)$$

$$C_i = 1000 \left(\frac{5000}{100} - 1\right) = 1000\ (50-1)$$

$$C_i = 49{,}000 \text{ pF}$$

Thus C_i may vary from very small values up to 49,000 pF in this case with a 1% change in output (49,000 pF corresponds to approximately 1500' of coaxial cable).

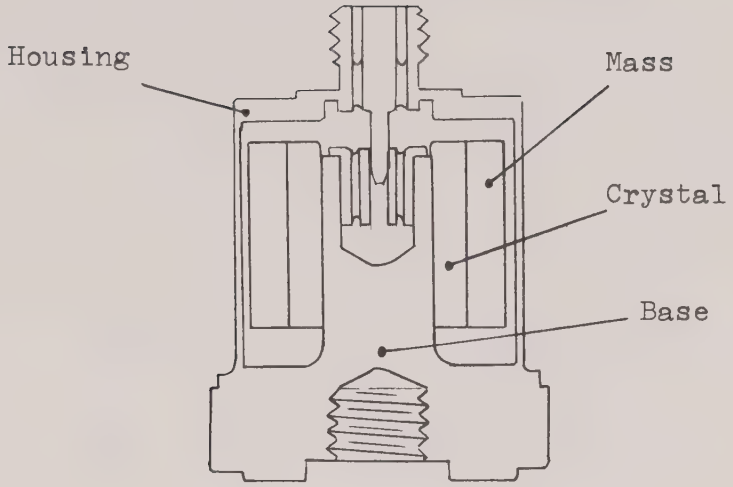


Fig 1: Shear Type Design

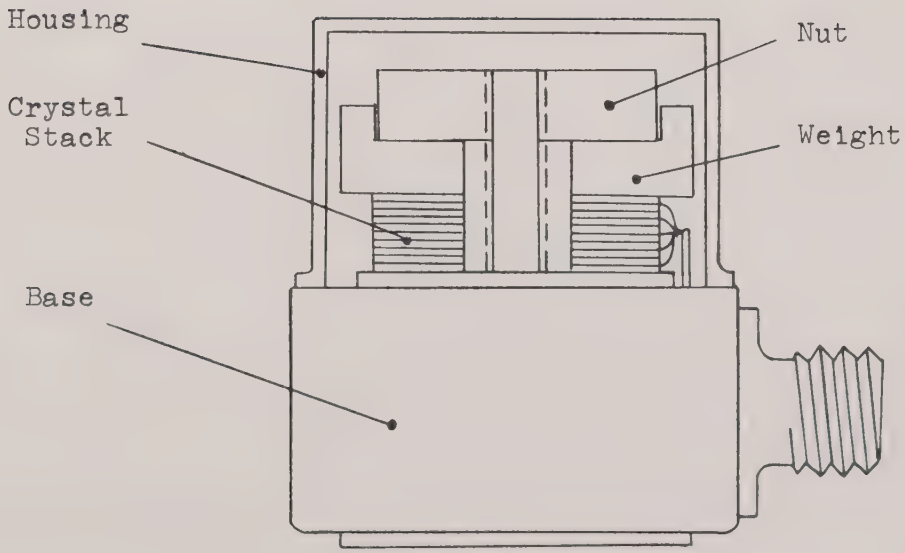


Fig 2: Compression Type Design

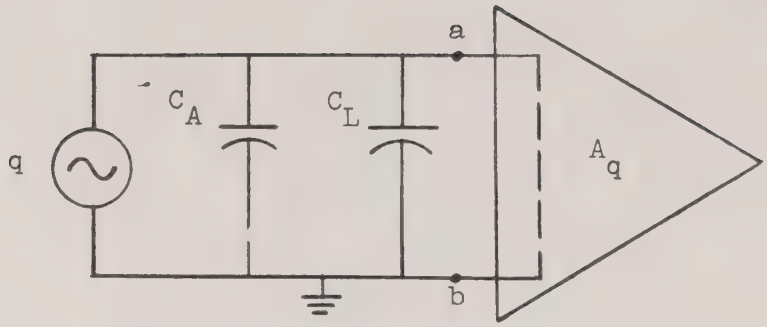


Fig 3 = Charge Equivalent Circuit into a Charge Amplifier

V_{ab} = 0 because of virtual ground in charge amplifier

C_A = accelerometer capacitance

C_L = load capacitance (cable + input)

A_q = charge amplification

A_v = voltage amplification

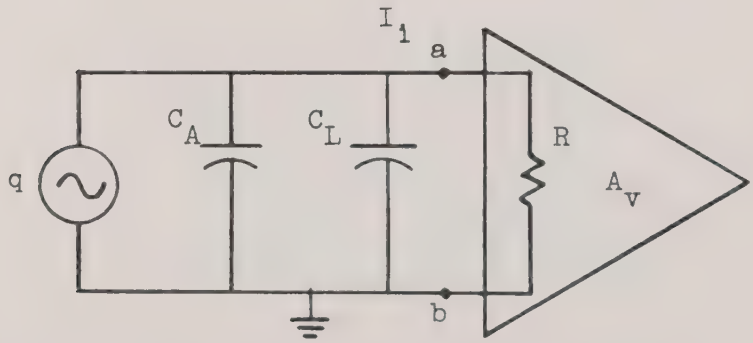


Fig 4. Charge Equivalent Circuit into a Voltage Amplifier

I_1 = 0 because of large input resistance R.

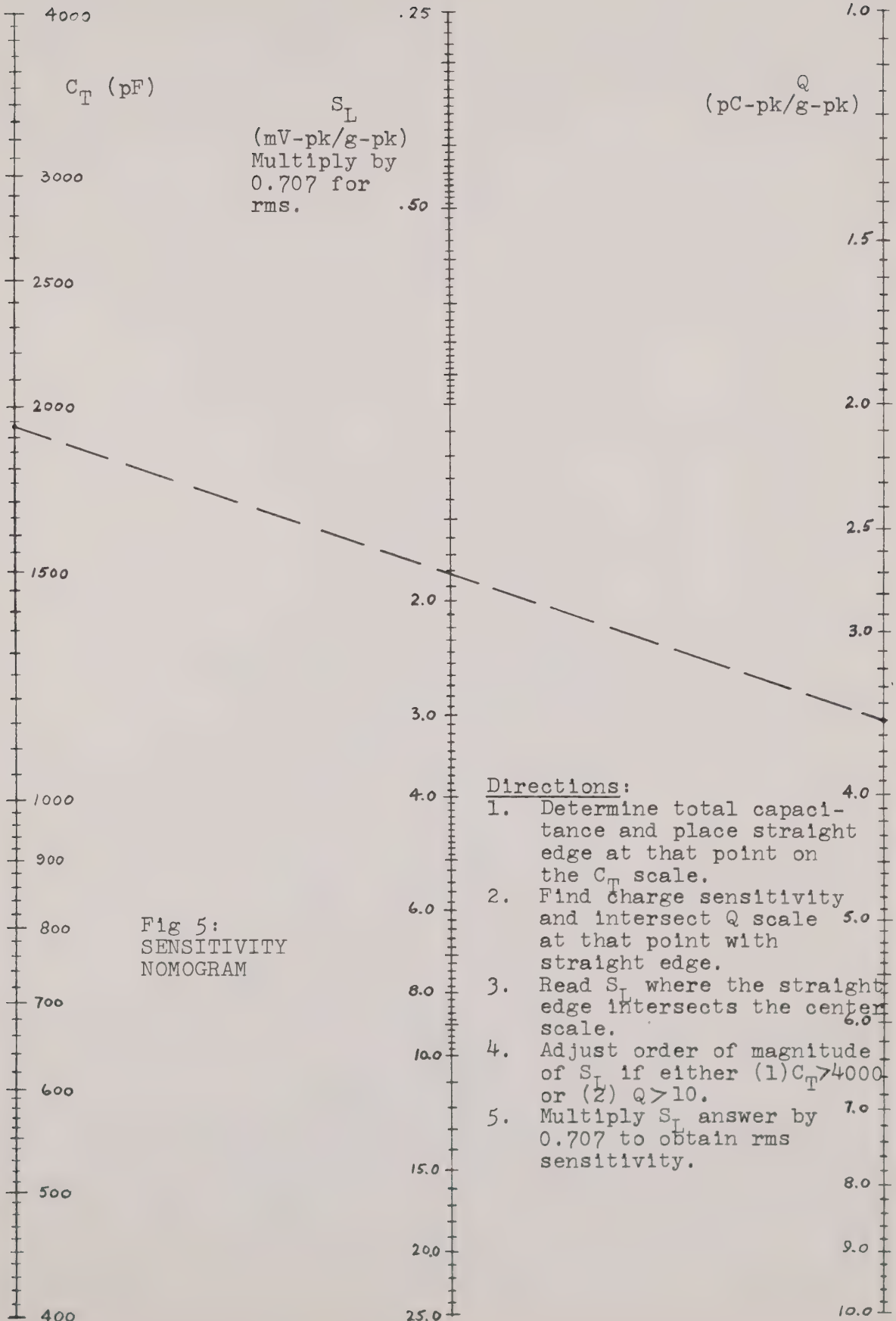


Fig 5:
SENSITIVITY
NOMOGRAM

Directions:

1. Determine total capacitance and place straight edge at that point on the C_T scale.
2. Find charge sensitivity and intersect Q scale at that point with straight edge.
3. Read S_L where the straight edge intersects the center scale.
4. Adjust order of magnitude of S_L if either (1) $C_T > 4000$ or (2) $Q > 10$.
5. Multiply S_L answer by 0.707 to obtain rms sensitivity.

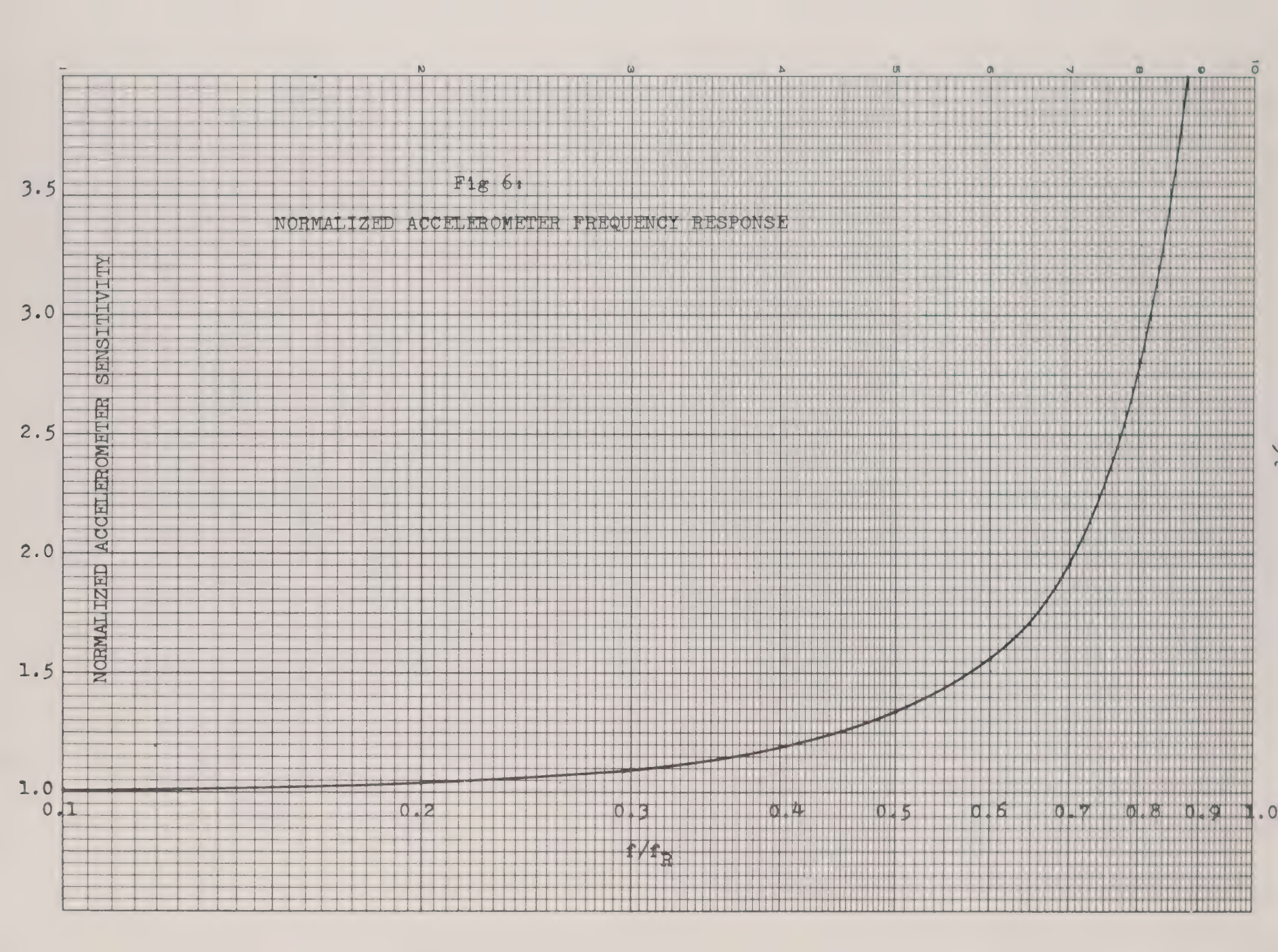


Fig 6.
NORMALIZED ACCELEROMETER FREQUENCY RESPONSE
NORMALIZED ACCELEROMETER SENSITIVITY
3.5
3.0
2.5
2.0
1.5
1.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
f/f_R

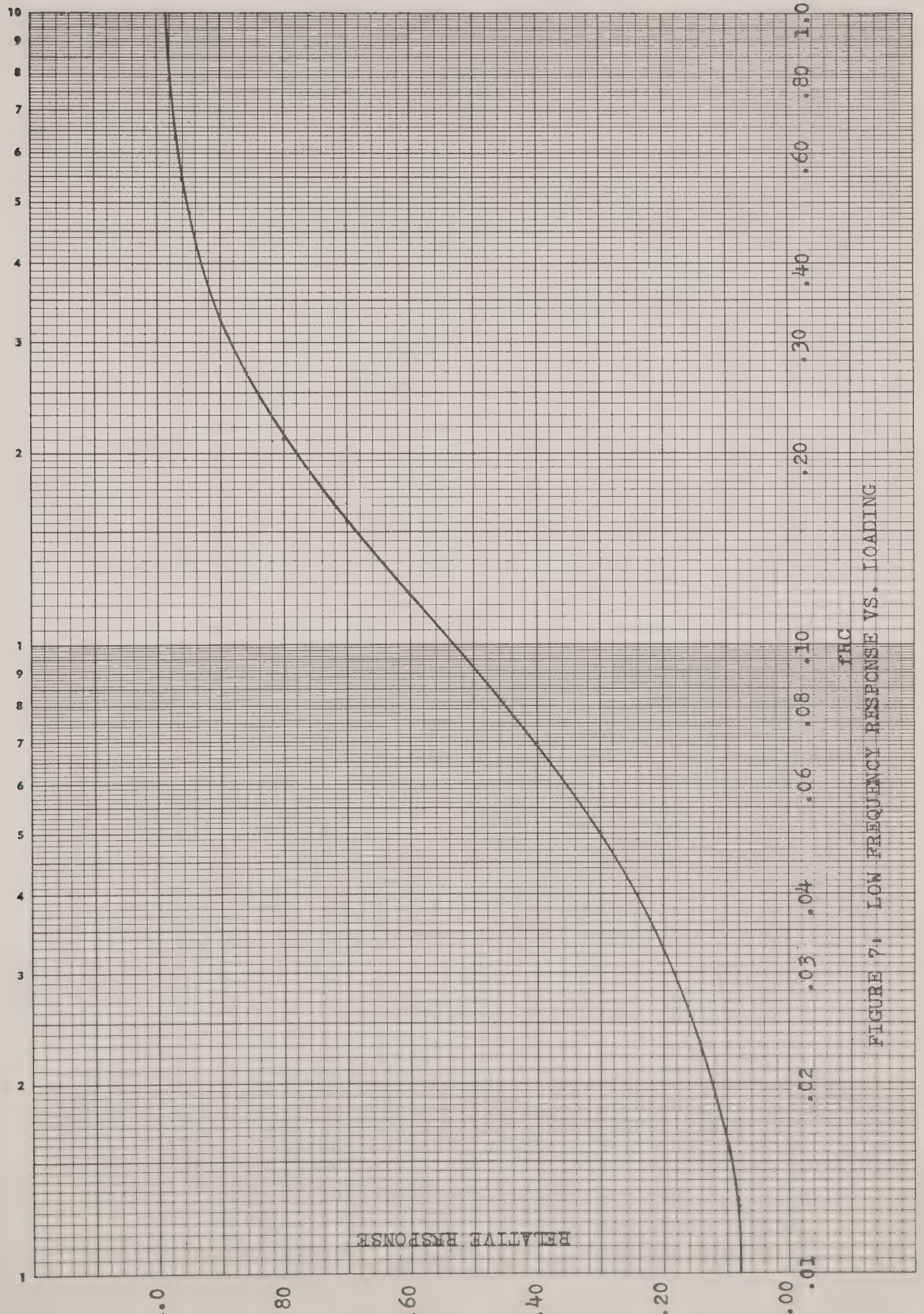


FIGURE 7: LOW FREQUENCY RESPONSE VS. LOADING

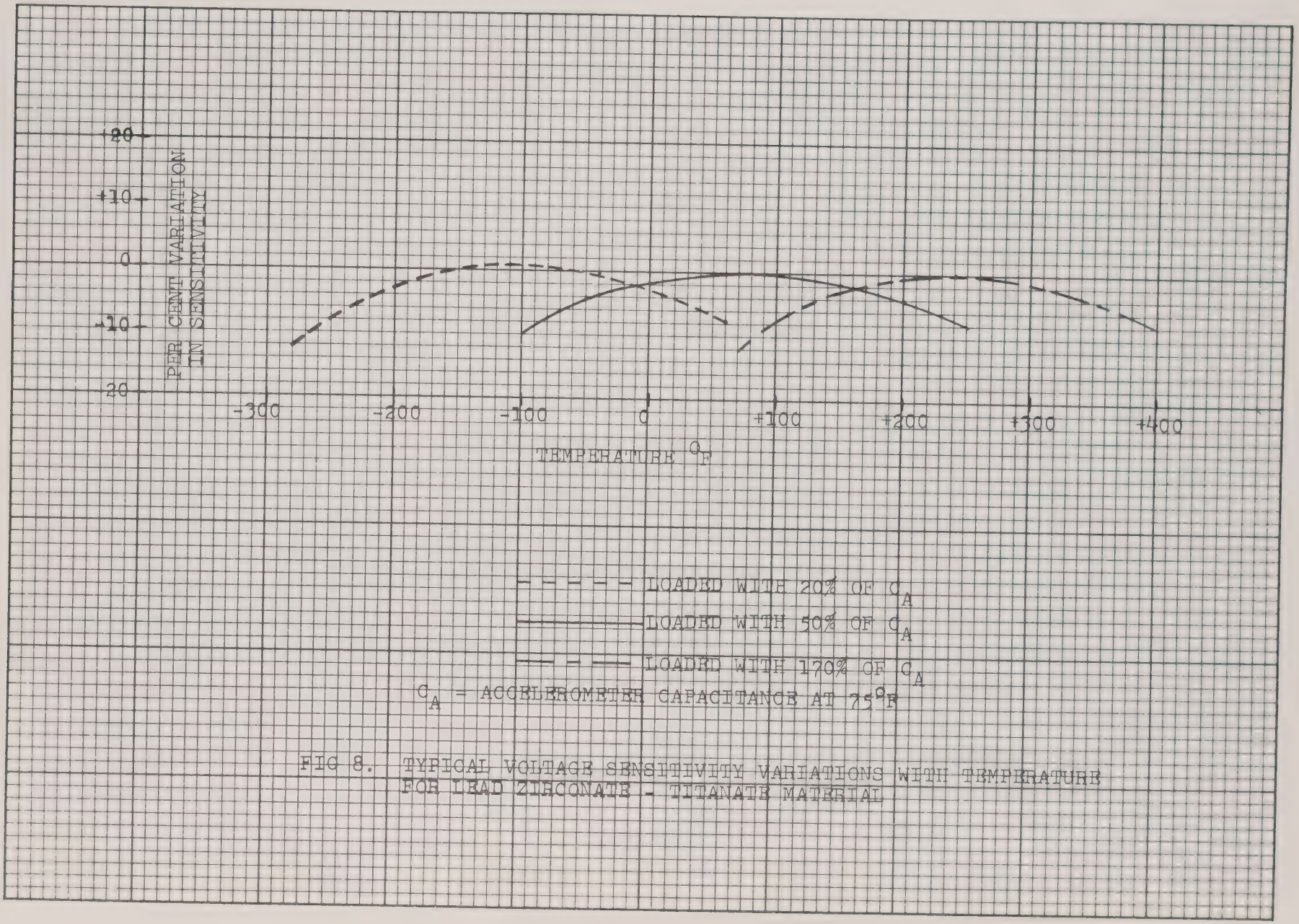


FIG 8. TYPICAL VOLTAGE SENSITIVITY VARIATIONS WITH TEMPERATURE FOR LEAD ZIRCONATE - TITANATE MATERIAL

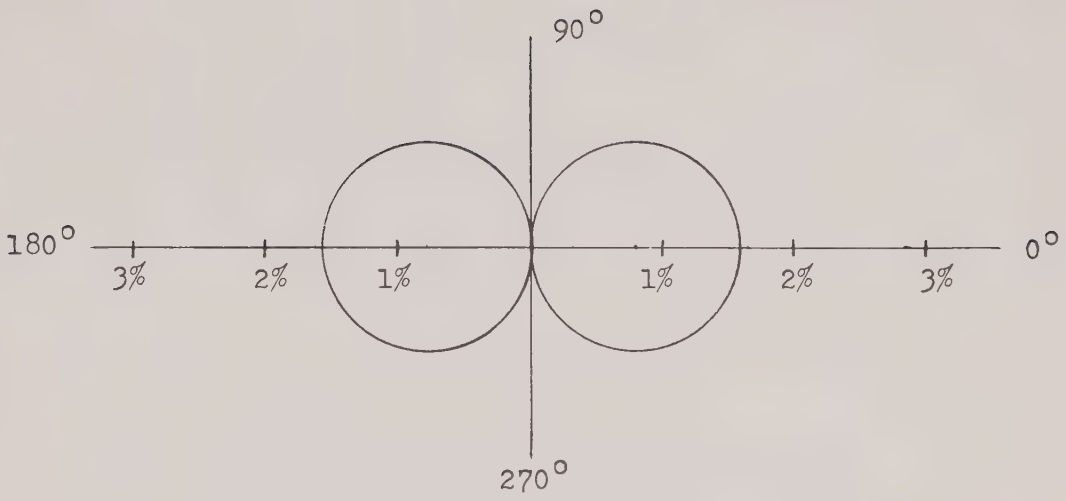
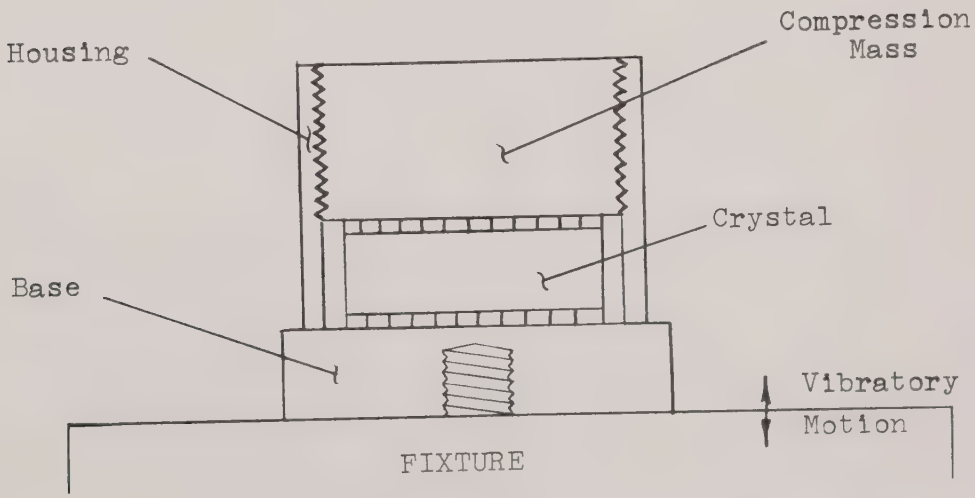


Fig 9: Polar Plot of Accelerometer Cross-Axis Sensitivity

Fig 10. Poor Accelerometer Design



(1) Stress on housing leads to movement of compression mass and production of unwanted output

(2) Base strain is easily transmitted through thin base to crystal, producing an unwanted output

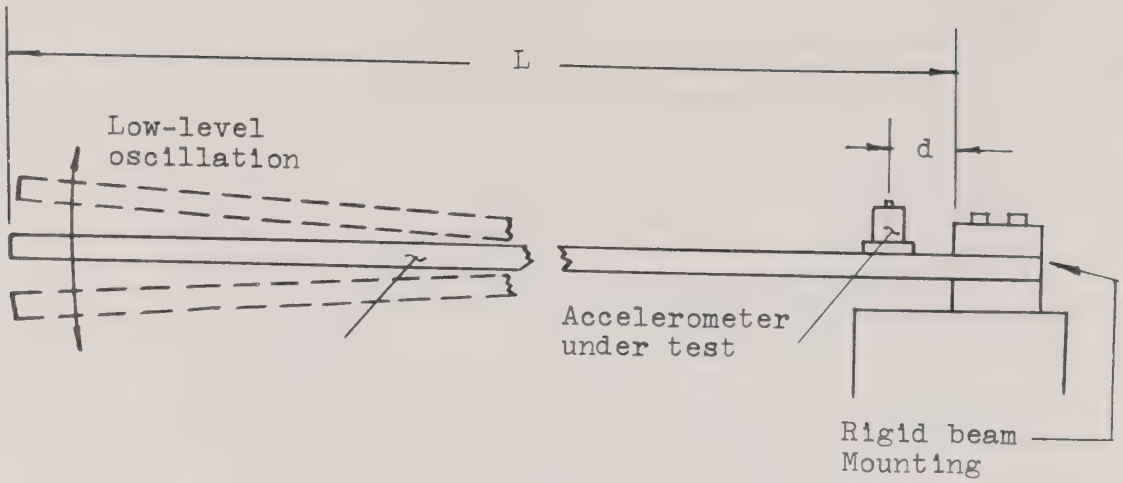


Fig 11. Test Method for Base Strain Sensitivity = Adapted from the ISA Standard RP37.2, para 6.6

An oscillatory displacement at a low g-level at the free end of the beam produces a surface strain on the beam which is transmitted to the accelerometer base. Since L>> d, the oscillation at the point where the accelerometer is mounted is much less than at the beam end. Therefore only the accelerometer output due to the base strain will be significant.

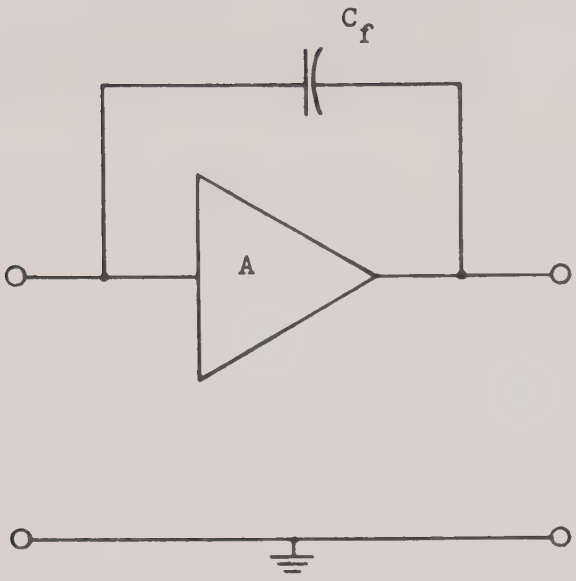


Fig. 12

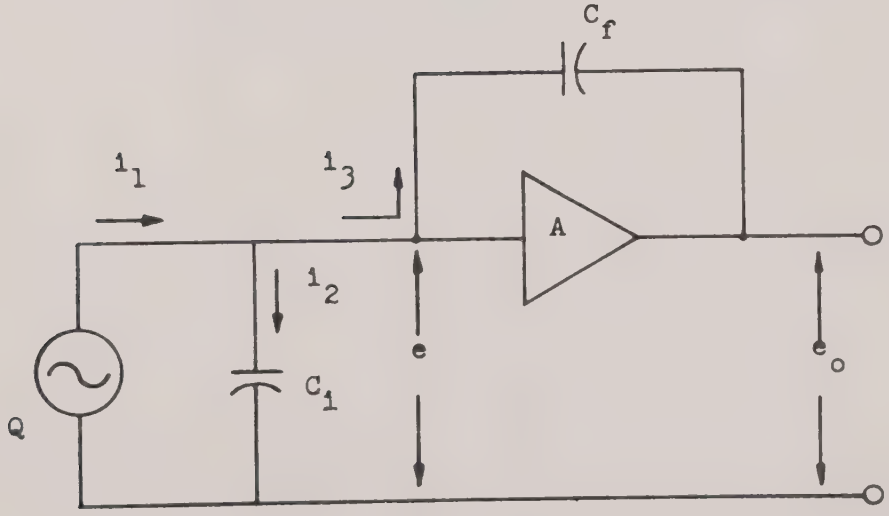
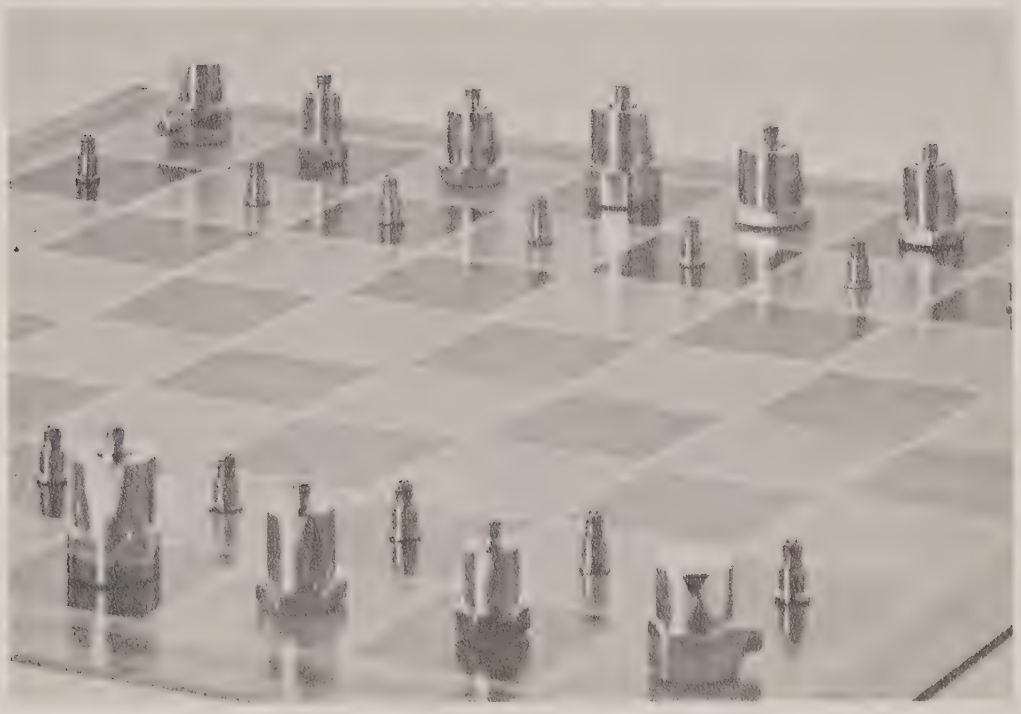


Fig. 13

ACCELEROMETERS



A full line of piezoelectric self-generating accelerometers are produced by Unholtz-Dickie for general purpose vibration testing and for special applications. Various models are optimized to provide features such as subminiature size, high sensitivity, high frequency operation, high temperature operation, and normalized 10 pC/g sensitivity for special applications.

Unholtz-Dickie accelerometers operate over wide acceleration and frequency ranges. Typically, accelerations from a fraction of a g to 1000 g's may be sensed, and upper frequency limits of 4 kHz to 12 kHz are attainable. Special design features limit case and base strain sensitivities.

Unholtz-Dickie also offers a wide range of signal conditioning charge and voltage amplifiers for use with piezoelectric accelerometers. Conditioned signals are produced for servo control purposes, for direct recording, for log-log frequency response plotting, and for meter indication of acceleration, velocity, or displacement. Special circuit features allow very low frequency operation with piezoelectric accelerometers.

NEW

The Model 10B10 is factory adjusted to exactly 10.0 pC/g charge sensitivity. Data acquisition is greatly simplified using this standardized output.

NEW

ACCELEROMETERS

MODEL	PERFORMANCE FEATURES	NOMINAL: OPEN-CIRCUIT VOLTAGE SENS. mV-pk/g-pk	NOMINAL: CHARGE SENSITIVITY pC-pk/g-pk	NOMINAL: USEFUL FREQUENCY RANGE-Hz	NOMINAL: MOUNTED RESONANT FREQUENCY-KHz	SIZE-INCHES WEIGHT-GRAMS	DESIGN FEATURES	PRICE EACH *
2E3	Subminiature, extremely small, lightweight, for highest frequencies and minimum added mass.	2.5	1.0	1.0 TO 12000	70	HT .310 DIA .220 WT 1.22	Shear, side connector, integral cable, molded neoprene strain relief boot, adhesive mount, lead zirconate-titanate crystal. 2E5 has wrenching flats for easy removal.	$213.00
2E5	Relatively large voltage and charge outputs. Low base strain sensitivity construction.					HT .310 DIA .280 WT 1.36		
2D21	Subminiature, lightweight, with low base strain sensitivity construction. Removeable cable.	3.0				HT .415 DIA .280 WT 1.31	Shear, top connector, wrenching flats for easy removal, lead zirconate-titanate crystal.	
5D21-8	Miniature, general purpose, moderately high resonance, low base strain sensitivity, recommended for charge use.	5.0	8.0	0.2 TO 7000	40	HT .64 HEX .50 WT 10.7	Shear, top connector, 10-32 mounting hole, lead zirconate-titanate crystal. Stainless steel case.	$185.00
5D21	Miniature, general purpose, similar to 5D21-8. Low base strain sensitivity.	8.7	14			HT .64 HEX .50 WT 13		
10DQ21	General purpose, side connector for restricted height applications. Low base strain sensitivity.	20	40	0.2 TO 6000	30	HT .71 HEX .62 WT 25	Shear, side connector, 10-32 mounting hole, lead zirconate-titanate crystal. Stainless steel case.	
20D21	General purpose, top connector, recommended for voltage use with 35 foot low noise cables. Low base strain sensitivity.	22	35	0.2 TO 6000		HT .71 HEX .62 WT 23	Shear, top connector, 10-32 mounting hole, lead zirconate-titanate crystal. Stainless steel case.	
75D21	Maximum voltage and charge sensitivity gives best signal/noise ratio for low level measurements. Low base strain sensitivity.	75	82	0.3 TO 4000	20	HT .74 HEX .75 WT 37		
8B6	Wide temperature range, – 300°F to +500°F, flat voltage and charge sensitivities. Stainless steel case. Recommended for calibrator.	2.9	7.5	1.0 TO 5000	30	HT .88 DIA .76 WT 36	Double base, compression, top connector, 10-32 mounting hole. Bismuth strontium-titanate crystal. Stainless steel case.	$220.00
10B10	Charge sensitivity normalized at 10 pC/g. Wide temperature range, – 300°F to +500°F. Flat voltage and charge sensitivities. Low base strain sensitivity.	3.1	Set at exactly 10.0	1.0 TO 4000	25	HT .78 HEX .62 WT 27	Double base, compression, side connector, 10-32 mounting hole. Bismuth strontium titanate crystal. Stainless steel case.	$225.00
10B10T						HT .81 HEX .62 WT 29.5	Same as 10B10 but with top connector.	$235.00
A-1 Probe	General purpose hand-held accelerometer for vibration survey.	3.5	5.2	0.3 To 600 (hand-held)	NA	LGH 5.25 DIA .62	Shear mode, hand-held, aluminum case with stainless steel tip	$250.00

UNHOLTZ-DICKIE CORPORATION

3000 Whitney Avenue, Hamden, Connecticut, 06518

Area Code (203) 288-3358

Bulletin ACC-72
Printed in U.S.A.

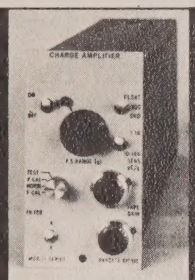
UNHOLTZ-DICKIE CORPORATION

vibration generation systems and measurement instruments

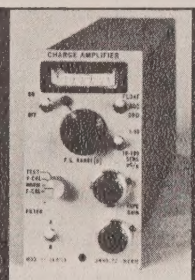
Signal conditioning amplifiers for shock and vibration monitoring

This popular series of signal conditioning amplifiers features individual double shielded power supplies, a totally-enclosed-vinyl-clad case, portability of separate units, ultra low noise levels, frequency response to 100 kHz, and switchable low pass filters with an 18 dB/octave attenuation rate. They can be operated in the integral charge mode with direct connection to the piezoelectric transducer, or switched to the remote preamp mode for operation with either the two-wire charge type remote preamp or the two-wire voltage type remote preamp. Full scale ranges of .1 g to 10 Kg with accelerometer sensitivities from 1 pC/g to 100 pC/g are standard. Also offered is Option III full scale ranging to provide an extra gain of 10 for very low level measurements. Panel height is only 5¼ inches when standard edgewise meters are selected.

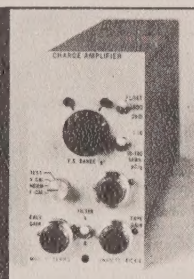
D11V SERIES



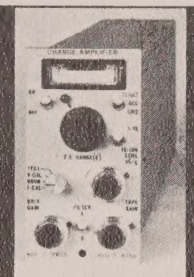
Model D11V
Tape output only
$525.00



Model D11MV
Tape and meter
$575.00



Model D11GV
Tape and galvo
$590.00



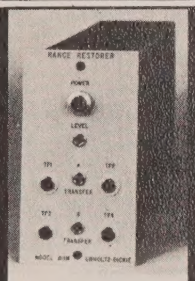
Model D11MGV
Tape, galvo, meter
$640.00

Basic D11V series permits operation with grounded transducers while eliminating usual ground loop problems. Differential circuitry provides rejection of common-mode signals by a factor of 1000. The two-wire remote preamps shown below can be used with any of the D11V series instruments.

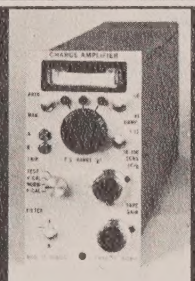
OPTIONAL FEATURES

L	Log dc output with 60 dB dynamic range (requires meter feature)	$175.00
S	Normalized 10 mV/g servo output for full scale ranges up to 300 g	$50.00
O	1 kHz fixed amplitude, sine wave, internal calibration oscillator	$50.00
—8	Large meter with 2½ inch scale length and 8¾ inch panel height	$20.00
—2	Extended low frequency response flat within ±5% down to 0.5 Hz	$25.00

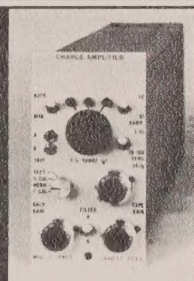
AUTORANGER SERIES



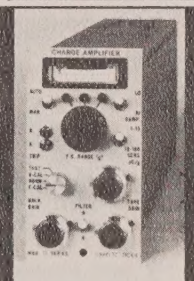
Model 811M
Range restorer
$1200.00



Model 11MAV
Tape and meter
$745.00



Model 11GAV
Tape and galvo
$760.00



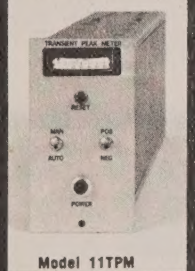
Model 11MGAV
Tape, galvo, meter
$810.00

AUTORANGER series selects best of 3 adjacent full scale ranges. Pilot light and dc code signals indicate range selected. Range sequences of 1, 3, 10 . . ., or 10 dB steps, or 1, 10, 100, 1K are offered. Companion RANGE-RESTORER converts tape recorded data to original dynamic range. The two-wire remote preamps shown below can be used with any of the AUTORANGER instruments.

OPTIONAL FEATURES

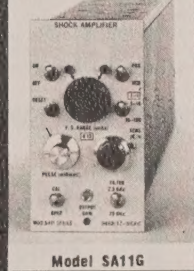
S	Normalized 10 mV/g servo output for full scale ranges up to 1 Kg	$50.00
O	1 kHz fixed amplitude, sine wave, internal calibration oscillator	$50.00
F	Linear DC output for amplifiers supplied with meter feature	$25.00
—8	Large meter with 2½ inch scale length and 8¾ inch panel height	$20.00

SHOCK SERIES



Model 11TPM
Transient peak meter
$350.00

Model SA11TPM
Shock amplifier with tape and transient meter
$875.00



Model SA11G
Shock amplifier with adjustable galvo output
$615.00

Model SA11MG
Shock amplifier with galvo, and standard meter
$665.00

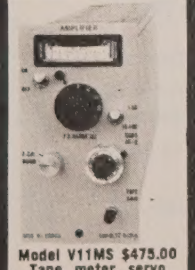
Shock amplifiers have selectable low and high frequency time constants for pulse durations from 100 microsec to 100 millisec. Reset feature and direct coupling provide rapid stabilization. Series shown at left can be intermixed with other series 11 instruments. Series described below are housed in a single portable carrying case that can be rack mounted as one, two or three units.

PORTABLE SHOCK INSTRUMENTS

Model SA11GO-3	Portable shock amplifier with galvo and internal oscillator
Model 11TPM-3	Portable transient peak meter for pulse measurements
Model 11RA-3	Rack adapter for 1 to 3 of the portable units above.

OPTIONAL FEATURES

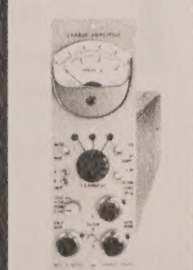
1 kHz Osc. $50.00 10 mV/g Servo $50.00



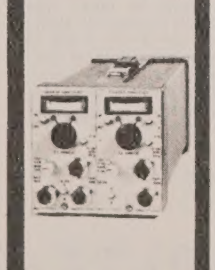
Model V11MS $475.00
Tape, meter, servo
Economy model operates exclusively with two-wire remote charge or voltage preamp shown at right.
Galvo option $65.00
OSC option $50.00

Model 11CA-2 $90.00
Remote charge preamp
Will operate with any series D11V or Autoranger instrument.

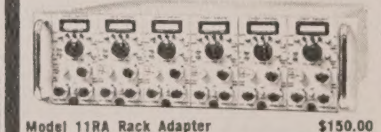
Model 11PA-2 $50.00
Remote voltage preamp
Will operate with any series D11V or Autoranger instrument.



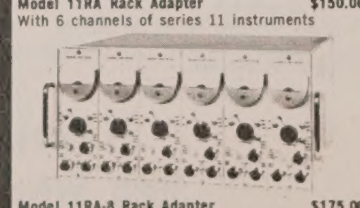
Series 11 instrument with —8 meter option.



Model 11P-2 $70.00
Dual channel Portable adapter
With 2 channels of series 11 instruments

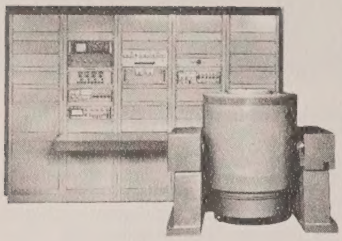


Model 11RA Rack Adapter $150.00
With 6 channels of series 11 instruments

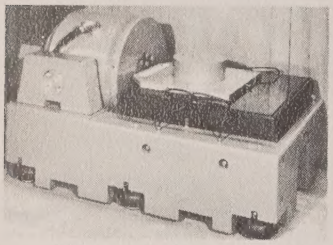


Model 11RA-8 Rack Adapter $175.00
With 6 channels of series 11 instruments with —8 meter options

Complete vibration test systems



15000 lb system with solid state amplifier



Shaker and slip table on seismic base

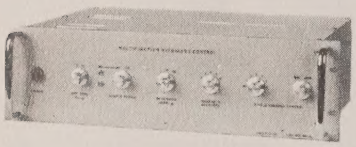
SYSTEM	SYSTEM	SHAKER TABLE					SYSTEM COOLING		
								SHAKER	
Model Number	Force Sine lbs.-pk	Stroke inches pk-pk	Bolt Circle Max. Dia.	Suspension Stiffness lbs/in.	Weight lbs.	Frequency Range - Hz	Amplifier	Moving Element	Field
TA 100-4	150	4	—	Nil	3	dc-1000	Air	Air	Air
TA 250-6	1000	6	—	Nil	11	dc-1000	Air	Air	Air
TA 50-20	200	1	3.5	80	2	dc-3000	Air	Air	Air
72-7	200	1	4.5	225	4	5-10000	Air	Air	Air
TA 250-100	350	1	4.5	225	4	dc-6000	Air	Air	Water
76-7	350	1	4.5	225	4	5-10000	Air	Air	Water
340-7	350	0.5	2.25	50	2.5	5-10000	Air	Air	Water
279	450	1	4.5	225	5.3	5-5000	Air	Air	Water
TA 161	1000	1	5.75	250	14	dc-2000	Air	Air	Air
262-8	1200	1	8	400	20	5-3000	Air	Air	Air
464-8	1700	1	8	400	20	5-3000	Air	Air	Air
454	1750	1.25	8	600	20	5-3000	Air	Air	Air
484H	2000	1.25	8	600	20	5-3000	Air	Air	Air
8208 AAA	2600	1.25	8	600	27	5-5000	Air	Air	Air
8208 AMA	3000	1.25	8	600	20	5-3000	Air	Air	Air
8208 PH	3000	1.25	5.75	300	14	5-2000	Air	Air	Air
691M-50	5000	1.25	12	1200	34	5-3000	Air	Air	Air
1596M-60	6000	1.25	12	1200	34	5-3000	Air	Air	Water
TA 1696M-60	6000	1.25	12	1200	36	dc-3000	Water	Air	Water
TA 1600M-80	8000	1.25	16	3000	90	dc-3000	Water	Air	Water
TA 3200M-100	10000	1.25	16	3000	90	dc-3000	Water	Air	Water
TA 13500-120	12000	1.25	16	3000	90	dc-3000	Water	Air	Water
TA 165-165	16500	1.25	16	3000	95	5-3000	Water	Air	Water
TA 1100D-220	20000	1.25	16	3000	95	5-3000	Water	Air	Water

Systems with TA in model number include all silicon, direct coupled, solid state power amplifiers.

MULTIPLE SHAKER SYSTEMS FOR LARGE LOADS, HIGH FORCE RATINGS, OR SPECIAL APPLICATIONS ARE AVAILABLE

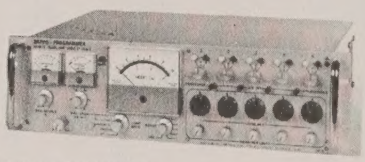
Accessory instruments

Shaker system controls and protective functions



MULTIFUNCTION AVERAGING CONTROL
Model MAC-6C

Features: Phase insensitive averaging for at least 6 inputs ■ Allows averaged shaker system control for sine and random tests ■ Sine tests: absolute average of output yields average of input magnitudes ■ Random tests: spectral density of output yields average of input spectral densities ■ Freedom from detector time constant problems ■ DC output for recording ■ Units may be coupled for more than 6 inputs

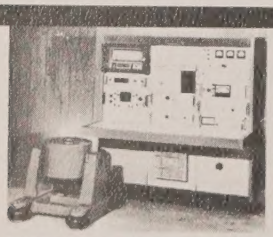


SERVO PROGRAMMERS
Models SP5 and SP2

Features: Combines functions of amplitude servo and vibration programmer in one instrument ■ Programmer contains up to five program segments with servo controlled acceleration, velocity or displacement selectable for each segment (SP5) ■ Simplified closed-loop presetting of vibration levels before actual test is performed ■ Optional safety shutdown at pre-set level of acceleration ■ Solid state, plug-in, printed circuit construction ■ Log dc output for X-Y recording of test

ACCELERATION CONTROL SELECTOR
Model ACS-6
Solid State Switching

Features: Automatically switches to highest (or lowest) accelerometer for amplitude servo control ■ Up to 6 input acceleration signals ■ Switching speed continuously variable with frequency ■ Weighted switching from .01 to 10 times nominal acceleration ■ Wide dynamic range ■ Pilot light indicates controlling channel.



Calibration systems for accelerometers

AUTOMATIC CALIBRATION SYSTEMS

Unholtz-Dickie automatic calibration systems, based on Model 106A shaker automatically plot accelerometer calibration curves of charge or voltage sensitivity vs. frequency to any level up to 100 g and 10 kHz. Original data is permanently plotted — eliminating operator error in readout and transcription. Continuous curve detects all variations, expansion or compression of vertical scale for optimum accuracy and readability of curves. One per cent accuracy of unknown accelerometer relative to reference.

ABSOLUTE CALIBRATION OPTICAL SYSTEM

Model DO-5000. New optical instrument gives digital readout of absolute displacement.

Piezoelectric accelerometers

Micro-miniature
0.8 grams
General purpose
high sensitivity

For accurate vibration measurements this D21 series of shear mode types insure freedom from case sensitivity and lowest cross axis sensitivity. A range of sizes covers most applications, down to a 0.65 gram sub-miniature model. This series uses Lead Ziconate-Titanate crystals. Also available are Bismouth composition crystals for high temperatures.

Tracking Filter $900.00

Bandwidth: fixed or 10% of center frequency.

Outputs: filtered AC at unity gain and DC proportional to log of filtered AC.

Mounting: use separately or with up to six in 11RA Rack Adapter

Model TF11

UNHOLTZ-DICKIE CORP.

3000 Whitney Ave. Hamden, Conn. 06518

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